The Plankton of Perseverance Harbour, Campbell Island, New Zealand[1]

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ABSTRACT: Surface plankton samples from Perseverance Harbour, Campbell Island, New Zealand, were analyzed and species presence was related to hydrological factors. The hydromedusae *Obelia geniculata* and *Phialella quadrata* and the ctenophore *Pleurobrachia pileus* did not occur when sea temperatures fell below 7° C. However, *Bougainvillia macloviana* was present throughout the year.

Larvae of decapod crustaceans were released immediately after sea surface temperatures began to rise from their winter minima. Spring samples were dominated by decapod crustacean larvae, but in 1967 abnormally low sea surface temperatures were recorded and few decapod crustacean larvae were collected. Hermit crabs released more larvae in both spring and autumn. Other crabs released most larvae in spring.

Perseverance Harbour has a typical inlet plankton and is influenced by both New Zealand and circumpolar subantarctic faunas. The seasonal cycles are typical of temperate rather than Antarctic waters.

PLANKTON STUDIES in the harbors of the New Zealand subantarctic islands have been restricted to a collection of medusae by the 1907 Royal Society Expedition (Benham, 1909; Russell, 1953) and a brief discussion on the plankton cycle from a year of sampling at the Auckland Islands (Dawbin, 1955). In this preliminary study the presence and seasonal occurrence of the plankton in a subantarctic harbor are described and some comparisons are made with the constituents which also occur in the more temperate conditions of Wellington Harbour (Wear, 1965).

Campbell Island (Fig. 1 and 2) is about 400 miles south of New Zealand in the subantarctic zone, at lat 52°25′ to 52°37′ S, long 169°00′ to 169°12′ E. Perserverance Harbour (Fig. 2) is one of three drowned glacial valleys on the eastern side of the island. The harbor is about 5 miles long and ends in a series of shallow coves at the western end. The meteorological station and boat wharf are near these coves at the base of Beeman Hill.

Burling (1961) showed that Campbell Island lies directly in the path of the Circumpolar Subantarctic Current. This carries water in a southeasterly direction along the western edge of the Campbell Plateau and to the south of the island. To the north there is an anticlockwise flowing water mass, the Bounty-Campbell Byral. Both current systems (Fig. 1) would be likely to transport to Campbell Island plankton species from other subantarctic and cold temperate regions.

The prevailing wind is from a westerly quarter. Strong winds, mainly westerly, tend to be more frequent in spring than in other seasons (de Lisle, 1964) and probably cause the removal of surface water from the east to west oriented harbor, with subsequent replacement by subsurface water from outside the harbor.

The mean annual rainfall is 57.2 inches. This is evenly spread throughout the year, with an average of 325 days of rain each year (de Lisle, 1965). Most of the large streams enter Perseverance Harbour at the western end and in Lookout Bay (Fig. 2). With the even spread of rainfall there is probably little annual fluctuation in salinity within the harbor.

The mean monthly sea surface temperature (for 1943–1955), mean monthly air tempera-

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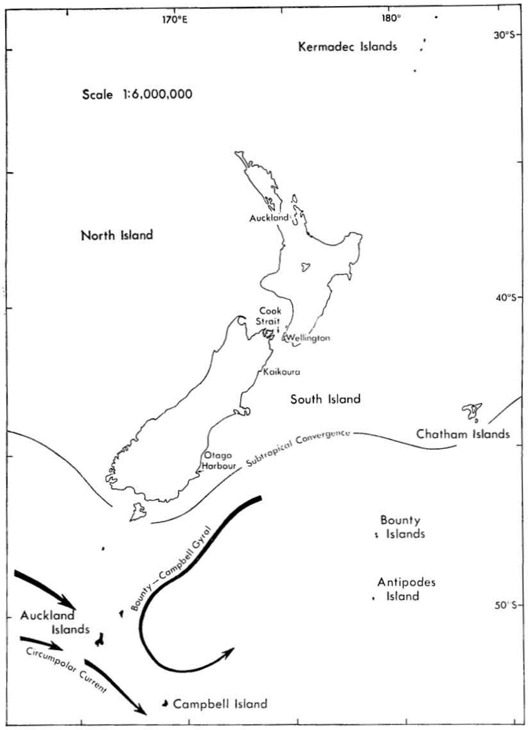


FIG. 1. The New Zealand region, showing the main oceanic current systems in the Campbell Island area.

ture (for 1941–1957) (from de Lisle, 1964, Table 11) and the mean and range of monthly sea surface temperature during the study period (1965–1967) are graphed (Fig. 3). The four seasons are defined by the mean air temperature with midsummer in January and midwinter in July.

Characteristic features of Perseverance Harbour water are, first, the small annual range of mean monthly sea temperature which is sometimes less than the daily range in a month. Second, sea surface temperature in the harbor is more influenced by air temperature than oceanic sea surface temperature. Oceanic temperature around Campbell Island is 7°–8° C in winter and 10°–11° C in summer (Garner and Ridgway, 1965) compared with 5.5°–7.5° C and 8.5°–10° C, respectively, inside Perseverance Harbour. Third, maximum temperatures are usually recorded in January or February and minimum temperatures in July or August, as in southern New Zealand harbors (Skerman, 1958).

MATERIAL AND METHODS

Plankton samples were collected between the wharf and Shoal Point at about fortnightly intervals by the meteorological staff on Campbell Island from March 1965 to February 1968. Few samples were collected during 1967, when no boat was available. The date, cloud conditions, and surface water temperature were recorded with each tow. Other meteorological data (mean monthly air and sea surface temperatures, wind, and rainfall) were obtained from the New Zealand Meteorological Service. As the samples were mostly taken in the absence of the author and by different members of the staff over the study period, no standardization was possible. The surface plankton tows were from 10 to 20 minutes' duration and were taken with a 2-ft-diameter cone net. The net mesh sizes were: 0.65 mm between March 1965 and November 1966 and 1.0 mm between December 1966 and February 1968. The plankton material was preserved in a solution of about 5 percent formalin soon after collection.

Because standardization of collection was not possible, a frequency index based on the presence or absence of a species in a sample was used for defining the seasonal occurrence of the more numerically important organisms: frequency of a species is equal to the number of samples in which the species occurred during the month divided by the total number of samples collected during the month.

A mean monthly frequency of each species was calculated for the whole 3-year sampling period. This was necessary because of inevitable gaps in the sampling routine (Table 1) through adverse weather and lack of a boat.

After the larger animals (salps, chaetognaths, and medusae) were removed, the decapod larvae were identified (Table 2) and counted as follows:

1. All larvae were counted in samples containing less than 5 ml settling volume of plankton.
2. One-fifth of the larvae was counted in samples containing up to about 25 ml of plankton. This was done by tipping the sample into a large petri dish placed on a piece of black paper divided into 10 equal segments. All larvae in any two segments

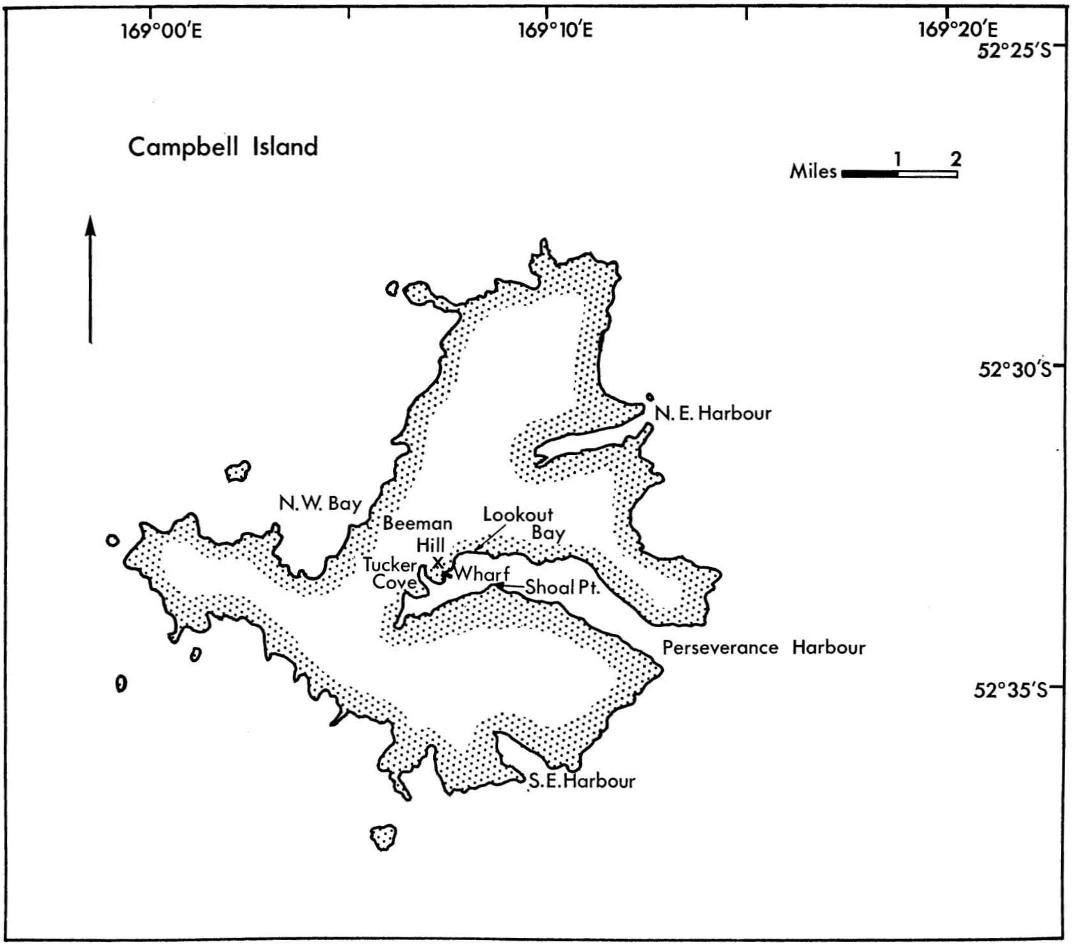


FIG. 2. Campbell Island, showing the position of Perseverance Harbour.

TABLE 1

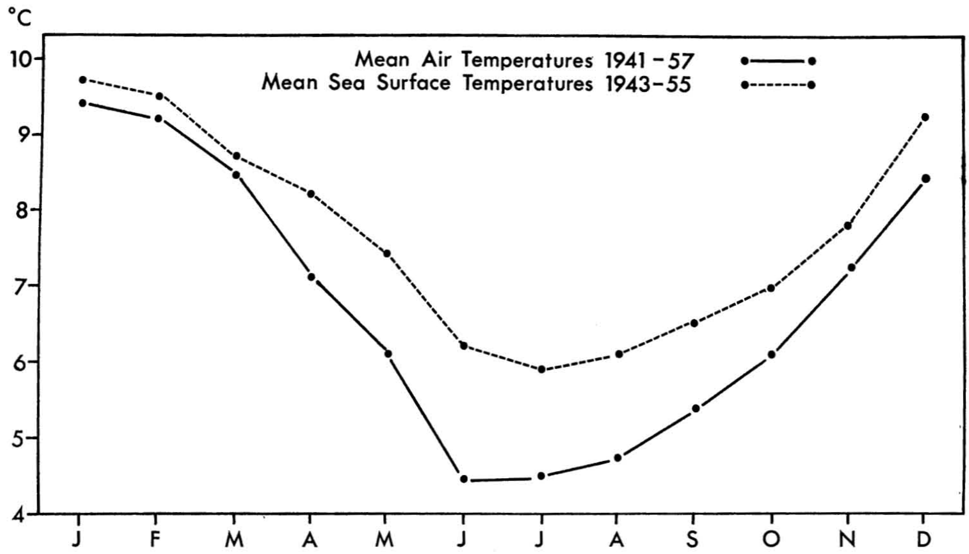
NUMBER OF PLANKTON TOWS COLLECTED EACH MONTH DURING THE SAMPLING PERIOD

MONTH	1965–66	1966–67	1967–68	Total
March	3	3	–	6
April	1	4	–	5
May	1	5	1	7
June	–	4	–	4
July	–	2	–	2
August	1	5	–	6
September	3	3	–	6
October	2	4	5	11
November	3	5	6	14
December	3	7	–	10
January	3	–	23	26
February	3	1	17	21

were counted and used to estimate the total.

3. A sample containing more than 25 ml of plankton was diluted to 2,000 ml. This was stirred with a 50-ml beaker, and a subsample was taken off with the beaker while the sample was in motion. The subsample was allowed to settle in a 50-ml measuring cylinder, and further subsamples were added until about 10 ml of settled plankton were obtained. One-fifth of the larvae was then counted as in (2) above.

The mean or average date of the period during which the first stage zoea larvae of the decapod Crustacea were collected was deter-



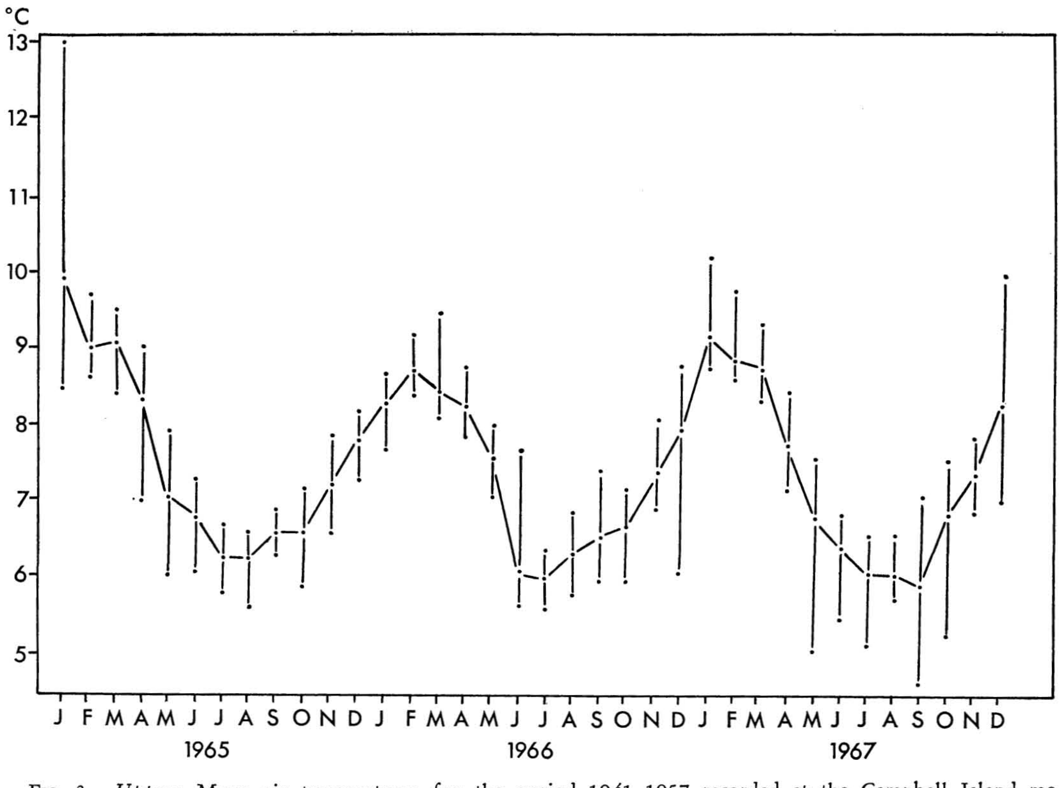


FIG. 3. *Upper*: Mean air temperatures for the period 1941–1957 recorded at the Campbell Island meteorological station and mean sea surface temperatures for the period 1943–1955, recorded in Tucker Cove, Perseverance Harbour. *Lower*: Mean and range of sea surface temperatures for the period 1965–1967, recorded at the Beeman Cove wharf.

TABLE 2

THE PLANKTON OF PERSEVERANCE HARBOUR

PHYTOPLANKTON

Rhizosolenidae
- *Rhizosolenia styliformis* Brightwell

ZOOPLANKTON

Coelenterata
- *Bougainvillia macloviana* Lesson
- *Obelia geniculata* (L.)
- *Phialella quadrata* (Forbes)
- 1 species (unidentified)

Ctenophora
- *Pleurobrachia pileus* (O. F. Müller)

Annelida
- Polychaeta
  - Tomopteridae
    - 1 species (unidentified)
  - 1 family (unidentified)
    - 1 species (unidentified)

Mollusca
- Cephalopoda
  - 1 species (unidentified)

Arthropoda
- Crustacea
  - Cirripedia
    - 2 species (unidentified)
  - Ostracoda
    - *Paracypris* sp.
    - *Halocypris* sp.
  - Copepoda
    - *Calanus tonsus* Brady
    - *C. australis* Brodsky
    - *Eucalanus longiceps* Matthews
    - *Eucalanus* sp.
    - *Euchaeta* sp.
- Malocostraca
  - Stomatopoda
    - *Heterosquilla spinosa* (Wood-Mason)
  - Mysidacea
    - *Tenagomysis tenuipes* Tattersall
  - Amphipoda
    - *Parathemisto gaudichaudii* (Guérin)
  - Euphausiacea
    - *Thysanoessa macrura* G. O. Sars
      - larval and juvenile forms
    - 1 species (unidentified)
  - Decapoda
    - Hippolytidae
      - *Nauticaris marionus* Bates
    - Galatheidae
      - *Munida subrugosa* (White)
    - Paguridae
      - *Pagurus campbelli* Filhol
      - *Pagurus* sp.
      - *Porcellanopagurus edwardsi* Filhol

TABLE 2 (*continued*)

ZOOPLANKTON

- Hymenosomidae
  - *Halicarcinus planatus* (Fabricius)
- Portunidae
  - 1 species (unidentified)
- Majidae
  - 1 species (unidentified)

Chaetognatha
- *Flaccisaggita gazellae* (Ritter-Zahony)
- *Serratosagitta tasmanica* (Thomson)

Chordata
- Thaliacea
  - *Salpa maxima* Forskål
  - *Iasis zonaria* Pallas
- Larvacea
  - 1 species (unidentified)
- Vertebrata
  - *Rhombosolea tapirina* Günther
  - *Gastrocymba quadriradiata* Randahl
  - fish larvae (5 species)
  - fish eggs (numerous species)

mined in the following way. The first day on which larvae of a species were collected in a plankton sample was designated day 1 for that species. All following days were numbered successively from this until first stage zoea larvae of the species were consistently absent from samples. The mean date of larval abundance was calculated with the following formula:

$$\bar{x} = \frac{\Sigma(f\,x)}{n},$$

where x is day number, $\bar{x}$ is mean day number, f is number of zoea larvae in a sample, and n is total number of larvae caught during the breeding period.

The figures obtained gave an indication of the period over which most first stage zoea larvae of a species were present in the plankton. This was taken as a measure of the most favorable breeding time of that species.

RESULTS

One species of phytoplankton and 22 species of zooplankton were identified from the plankton samples, and numerous other zooplankton species were recorded, but not identified (Table 2).

Phytoplankton

Phytoplankton was not usually sampled by the nets used in this study. Large quantities of *Rhizosolenia styliformis* Brightwell were present in five samples collected between 3 March and 2 May 1965, probably because of clogging of the net meshes, but no further specimens were collected over the following 3 years of sampling (Fig. 4). Cassie (1960: 155) showed that this species was common in the winter and spring phytoplankton of southeastern Cook Strait waters.

Zooplankton

COELENTERATA: *Bougainvillia macloviana* Lesson occurred throughout the year and had two periods of peak frequency, in August–September and January–March (Fig. 4). Medusae of *B. macloviana* occur in the North Sea usually in summer (Russell, 1953). Browne and Kramp (1939) suggested that this species has a very long breeding season in the Antarctic, and the Campbell Island collections support their hypothesis. This species does not occur in Wellington Harbour.

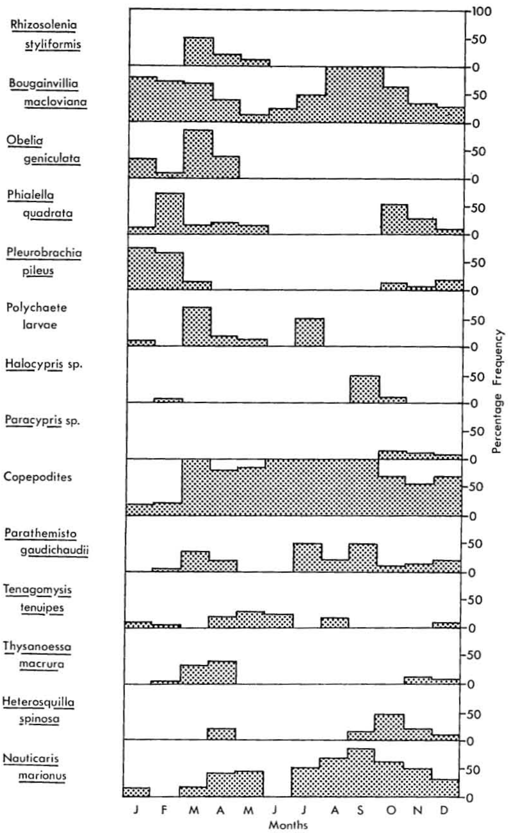


FIG. 4. Seasonal occurrence of plankton. Mean monthly percentage frequency of each of the species shown for the period of study, 1965–1968.

Obelia geniculata (L.) occurred only in summer and autumn (Fig. 4). As in Wellington Harbour (Wear, 1965), the medusae collected in early summer were smaller (1–2 mm in diameter) than those collected later (2–4 mm in diameter). In more temperate regions, such as Wellington Harbour, the medusae of *O. geniculata* occurred throughout the year, but were most common in the colder months (Wear, 1965, text-fig. 7) and less abundant from January to April.

Phialella quadrata (Forbes) was present from October to May (Fig. 4). This species has previously been recorded from the subantarctic islands by Benham (1909). Wear (1965) found that it occurs throughout the year in Wellington Harbour.

CTENOPHORA: *Pleurobrachia pileus* (O. F. Muller) occurred from October to March (Fig. 4) and most specimens were collected in January and February. Dakin and Colefax (1940) recorded that *Pleurobrachia* spp. in New South Wales waters were most common in summer and autumn, as in Perseverance Harbour. Wear (1965) stated that *P. pileus* was absent in Wellington Harbour in February and March, when temperatures rose above 15°–16° C, but was very abundant during other months.

COPEPODA: Copepodites were present throughout the year (Fig. 4) and were the most frequently caught planktonic animals. Adults of three species were recognized:

Calanus tonsus Brady occurred from October to March. Most specimens were collected in October and November 1967. The specimens were either stage 5 copepodites or adult females. This species is characteristic of the subantarctic regions of the Pacific, Indian, and Atlantic oceans (Vervoort, 1957). In southern New Zealand waters Jillett (1968) found that *C. tonsus* was more abundant in waters of subantarctic origin than in the waters of the warmer and more saline Southland Current. He stated that few specimens were collected from the inshore station of his study area, implying that *C. tonsus* was an oceanic rather than a neritic species. Both Grieve (1966*a*, *b*) and Jillett (1968) noted the swarming behavior of this species, especially during spring and summer, and Grieve pointed out the importance of this behavior in relation to pelagic fisheries. Some evidence of swarming was shown by the Perseverance Harbour collections when large numbers of *C. tonsus* were occasionally caught (up to 400–500 specimens per 15-minute tow, compared with four or five specimens of other species of copepod).

Calanus australis Brodsky occurred in May 1966 (one specimen), October 1967 (one specimen), and November 1967 (one specimen). This species is also regarded as an oceanic species (Brodsky, 1961).

Eucalanus longiceps Matthews—nine adult female and eight adult male specimens were collected during October and November 1967, and two copepodites in January 1966. *Eucalanus longiceps* is another oceanic species which was frequently collected by the *Terra Nova* Expedition in subantarctic and colder temperate waters (Farran, 1929). Vervoort (1957) stated that it seemed to be fairly common in the subantarctic.

STOMATOPODA: Late stage larvae of *Heterosquilla spinosa* (Wood-Mason) occurred from September to December (18 specimens) and in April (one specimen) (Fig. 4). Twelve of the 19 specimens were collected during October and November 1967. No early stage larvae were collected. Wear (1965) found that early stage larvae of *H. spinosa* are most common in Wellington Harbour from August to October. Adults of *H. spinosa* have not been recorded from Campbell Island but probably occur in waters outside the harbor. The early stage larvae would have been present in spring and it appears that the breeding season of this species is similar in Wellington Harbour and Perseverance Harbour.

MYSIDACEA: Larvae of *Tenagomysis tenuipes* Tattersall occurred occasionally from December to August (except March and July) (Fig. 4). All larvae were 3–5 mm long, which indicated that they were at an early stage of development (Bary, 1956) and that this species has a long breeding season in the subantarctic.

AMPHIPODA: Several juvenile specimens of *Parathemisto gaudichaudii* (Guérin) were examined and tentatively identified by Dr. D. Hurley, New Zealand Oceanographic Institute. Juveniles of the *compressa* form occurred in all months except January, May, and June (Fig. 4).

EUPHAUSIACEA: Juvenile stages of *Thysanoessa macrura* G. O. Sars occurred in small numbers in November and December and from February to April (Fig. 4). Rustad (1934) found swarms of young stages of *T. macrura* from October to February in Antarctic waters near the edges of ice floes. The breeding season of *T. macrura* appears to be similar in both Antarctic and subantarctic waters.

DECAPODA (HIPPOLYTIDAE): Larvae of *Nauticaris marionus* Bates occurred in the plankton in all months except February and June (Fig. 4). The number of stage 1 zoea larvae per 15-minute plankton tow has been graphed (Fig. 6). Larvae were more abundant from September to November. Larvae present after December were few and were in advanced stages of development. Larvae were three to four times more abundant in 1966 than in 1965 and only two zoea larvae were collected in the spring 1967 samples.

The peak of the breeding season (i.e., mid-breeding season) was calculated as described previously. The results (Table 3) show that stage 1 larvae were most abundant in October. In 1966 the greatest abundance occurred about 2 weeks earlier than in 1965. This was probably related to the earlier spring increase in sea surface temperatures for 1966 (Fig. 3).

DECAPODA (GALATHEIDAE): Larvae of *Munida subrugosa* (White) occurred from June to January (Fig. 5). These larvae were present in all samples (i.e., they had a frequency of 100 percent) collected from July to September and the frequency dropped in October and November. Most larvae caught were stage 1 zoeae. The duration of the stage 1 zoea is probably less than 14 days, so that it may be assumed that larvae were being released from June to November. (Boyd and Johnson [1963] showed that the mean duration of the stage 1

TABLE 3

MID-BREEDING SEASON OF THE DECAPOD CRUSTACEA

	MEAN DAY NUMBER ($\bar{x}$)		STANDARD DEVIATION (SD)		MID-BREEDING SEASON ($\bar{x} \pm$ SD)	
	1965	1966	1965	1966	1965	1966
N. marionus	22 Oct.	8 Oct.	21	8	1 Oct.–12 Nov.	30 Sep.–16 Oct.
M. subrugosa	23 Sep.	23 Sep.	3	3	20 Sep.–26 Sep.	20 Sep.–26 Sep.
P. campbelli	12 Oct.	23 Sep.	3	2	9 Oct.–15 Oct.	21 Sep.–25 Sep.
H. planatus	27 Sep.	24 Sep.	9	1	18 Sep.– 6 Oct.	23 Sep.–25 Sep.
Portunid	20 Sep.	25 Sep.	12	7	8 Sep.– 2 Oct.	18 Sep.– 2 Oct.
Majid	28 Oct.	25 Oct.	15	6	13 Oct.–12 Nov.	19 Oct.–31 Oct.

zoea of *Pleuroncodes planipes* Stimpson, a closely related galatheid, was 11.9 ± 5.7 days.) Megalopa larvae first appeared in the plankton in November or December.

Calculations of the number of larvae per 15-minute tow per month (Fig. 6) and of the peak of breeding season (Table 3) show that most larvae were released toward the end of September in both 1965 and 1966. Larvae were most abundant in 1966. At the peak of the breeding season in 1965 up to 5,000 larvae were caught in a 15-minute tow. In 1966 up to eight times as many were obtained.

In the Falkland Islands Rayner (1935) found that the most likely time for spawning of *M. subrugosa* was in September and October. He also suggested (from examination of berried females) that spawning continued throughout summer until March. In Campbell Island waters in the 2 years of observations the breeding season both began and finished earlier than at the Falkland Islands.

Munida gregaria Fabricius is often found in the same locality as *M. subrugosa* (Matthews, 1932). The breeding season of this second species coincides with that of *M. subrugosa.* Both Young (1952) (who kept specimens alive in the laboratory at Otago, New Zealand) and Rayner (1935) (from ovigerous females collected at the Falkland Islands) suggested a spawning date of September and October for *M. gregaria.* Wear (1965) reported a similar spawning date for the species in Tory Channel (on the western side of Cook Strait). Three females of *M. gregaria* collected in Cook Strait in March spawned in the laboratory in mid- and late August 1968. The available evidence indicates that the breeding seasons of both species of *Munida* overlap, with larvae of *M. subrugosa* beginning to develop in June or July, about a month earlier than those of *M. gregaria.*

DECAPODA (PAGURIDAE): *Pagurus campbelli* Filhol. Larvae of this species (described by Roberts, 1971) were found during all the months of the year (Fig. 5). Both spring and autumn peaks of frequency were apparent. The number of larvae per tow per month (Fig. 6) and the calculated peak of breeding season (Table 3) show that most larvae were collected in mid-October 1965 and late September 1966. This earlier breeding peak in 1966 was similar to that of *Nauticaris marionus.* Ovigerous females of *P. campbelli* were collected from November to February in Perseverance Harbour.

Pagurus sp. *A:* Larvae of *Pagurus* sp. *A* occurred in small numbers (one or two larvae per tow) from September to February and in May (Fig. 5). Insufficient numbers were caught to calculate a mid-breeding season. One ovigerous female was collected in January 1966. The breeding season, though shorter than that of *P. campbelli* (above), extended throughout late spring, summer, and autumn.

Porcellanopagurus edwardsi Filhol. Larvae of this species (described by Roberts, in press) occurred in small numbers (up to 40 specimens per 15-minute tow) in October, November, and February (Fig. 5).

Forest (1951), in a review of the literature on *Porcellanopagurus edwardsi,* stated that ovigerous females have been recorded in July and October. One ovigerous female was collected in Perseverance Harbour in March 1965.

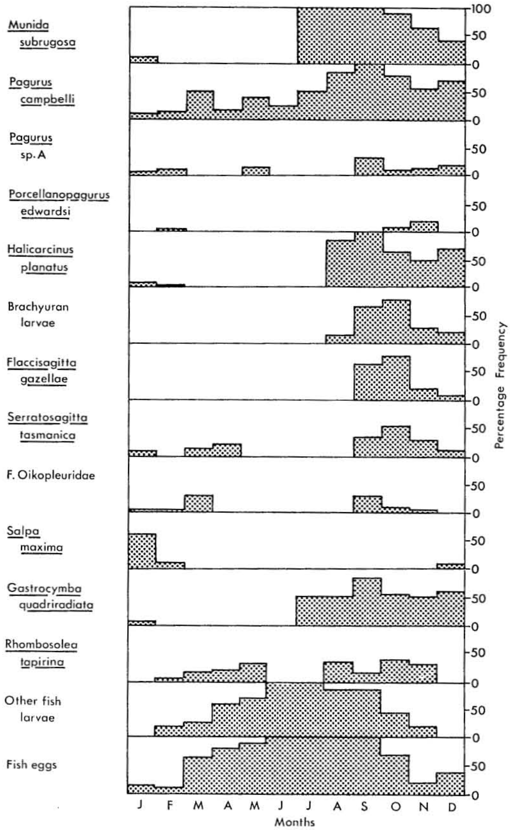


FIG. 5. Seasonal occurrence of plankton. Mean monthly percentage frequency of each of the species shown for the period of study, 1965–1968.

These records suggest that *P. edwardsi* also has two spawning periods during the year—in spring and in autumn.

BRACHYURA (HYMENOSOMIDAE): *Halicarcinus planatus* Fabricius. Larvae of *H. planatus* occurred from August to February (Fig. 5). Few larvae were caught after December (Fig. 6). The main breeding season was in late September (Table 3) in both 1965 and 1966. Only one larva was collected in spring 1967. Larvae were consistently more abundant in 1966 than in 1965. In 1966 up to 36,000 larvae were caught per 15-minute tow, but in 1965 no plankton tows contained more than 210 larvae.

In Wellington Harbour larvae of the genus *Halicarcinus* were present throughout the year (Wear, 1965) and were most abundant between July and November.

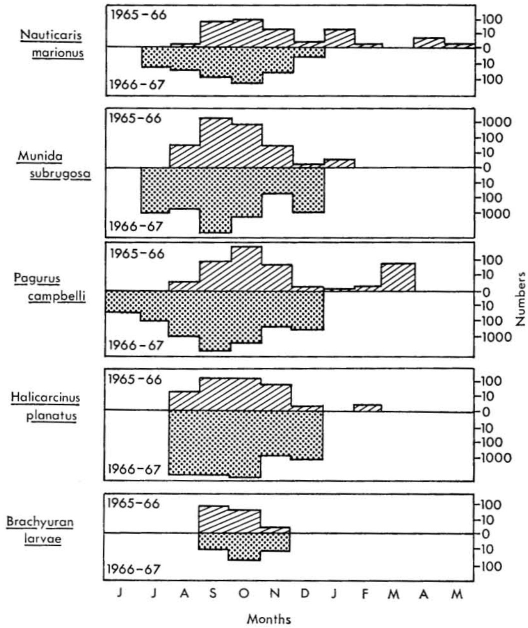


FIG. 6. Mid-breeding season of the decapod Crustacea. Mean monthly abundance of stage 1 zoea larvae of each species.

BRACHYURA (PORTUNIDAE AND MAJIDAE): Portunid and majid larvae (tentatively identified by R. G. Wear, Victoria University of Wellington) occurred from August to December (Fig. 5).

Larval numbers were small in both 1965 and 1966 (Fig. 6), and in 1967 only four specimens of portunid larvae and six specimens of majid larvae were collected (31 October 1967). The peak breeding season of the portunid was in late September (Table 3). This was about 1 month earlier than the peak breeding season of the majid in November.

One species of swimming crab (*Nectocarcinus antarcticus* [Jacquinot]) and two species of spider crab (*Jacquinotia edwardsi* [Jacquinot] and *Leptomithrax australis* [Jacquinot]) have been recorded from Campbell Island (Dell, 1968), but, as no ovigerous females of these species were collected during the study, the larvae could not be referred to their respective adults.

Ovigerous females of *J. edwardsi* have been collected during November from both Campbell Island (November 1956) and the Auckland Islands (8 November 1954) (Griffin, 1966). Bennett (1964) quoted a reference to swarming of adults of this species in August. As the swarming took place just before the breeding season, it was possibly related to reproductive behavior. Members of the Campbell Island staff have informed me that these large crabs are more frequently observed in Perseverance Harbour in October and November than at other times of the year. Swarming in shallow waters is possibly an adaptation to the problems of pair formation and provision of a suitable sea floor environment for the developing juveniles.

CHAETOGNATHA: (Nomenclature used as defined by Tokioka [1965].) *Flaccisagitta gazellae* (Ritter-Zahony) was present from September to December (Fig. 5). Forty-seven of the 57 specimens collected during the study period were caught during October and November 1967.

The specimens were separated into maturity stages according to David (1955: 241–244) by the degree of development of both male and female gonads. Of the four maturity stages proposed by David only the first two (immature) stages were represented in the Campbell Island plankton. David stated that the adults occurred below 500–750 m, and only the larval and immature stages were to be found in surface waters.

Stage 1 specimens (in which the male gonads were rudimentary, the tail segment was empty, and ovaries were either rudimentary or not visible) occurred from September to December. Stage 2 specimens (testes present as small protuberances, tail segment opaque, and ovaries short and thin and containing small eggs) were found only in October and November.

Serratosagitta tasmanica (Thomson) occurred in the plankton from September to January and in March and April (Fig. 5). Of the 217 specimens collected, 199 were captured during October and November 1967.

Mature and spent specimens (stages 2 and 4) were more common from October to December. Most of the specimens collected after December were in the first maturity stage. This suggests that the breeding season of *S. tasmanica* is in spring (October and November).

ACOPA: *Salpa maxima* Forskål. Both solitary and aggregate forms of this species occurred during December, January, and February (Fig. 5). When collected they tended to be so abundant as to clog the net. During January and February 1968, 40 plankton samples were collected along Perseverance Harbour. *Salpa maxima* was found to be most commonly collected near the harbor entrance, but occurred up to 3 miles into the harbor.

Iasis zonaria Pallas. A few specimens were collected during January 1968 in a plankton tow taken about 2 miles into the harbor. Waal (1964) also recorded this species in Perseverance Harbour, but no date was given.

Several specimens of *Oikopleura* sp. were collected between September and March, except in December (Fig. 5). *Oikopleura* was not recorded by either Dawbin (for the Auckland Islands) or Wear (for Wellington Harbour).

Vertebrata

Larvae of *Rhombosolea tapirina* Gunther (f. Pleuronectidae) occurred from August to November and from February to May (Fig. 5). This indicated a double spawning period (spring and autumn) for this species. A double spawning period is not unusual among some of the New Zealand species of this family (J. Manikiam, personal communication).

Gastrocymba quadriradiata Rendahl (f. Gobiesocidae). Fish larvae carrying a small sucker in the ventral position and attributed to this species occurred from July to January (Fig. 5). *Gastrocymba quadriradiata* was the most common fish larva in the samples.

Other fish larvae (five species) and fish eggs of numerous species occurred throughout the year (Fig. 5).

DISCUSSION

Just over half of the plankton species in Perseverance Harbour were Crustacea. The 22 species of Crustacea included eight species of decapods and five species of copepods. Herman, Mihursky, and McErlean (1968) found that the Crustacea made up 54 percent of the plankton species in the Patuxent Estuary, Maryland, and Wear (1965) showed that they constituted 86 percent of the Wellington Harbour plankton. Dakin and Colefax (1940) did not discuss all plankton groups in their collections, but showed that large numbers of crustacean species were present. Seventeen percent of all plankton species in Perseverance Harbour were fish larvae (compared with 15 percent in the Patuxent Estuary and about 7 percent in Wellington Harbour) and 10 percent were coelenterate (13 percent in the Patuxent Estuary and 3 percent in Wellington Harbour). All other plankton groups each made up less than 5 percent of the species in Perseverance Harbour. Species diversity in the Perseverance Harbour plankton is low compared with that of similar marine areas in lower latitudes. Whereas Wear (1965) recorded up to 46 species of decapod crustacean larvae from Wellington Harbour plankton, only eight species were collected in Perseverance Harbour.

The almost complete absence of plankton in winter is a feature of the Auckland Islands (Dawbin, 1955) and Antarctica (Foxton, 1964) and also appears to be characteristic of Campbell Island. In Wellington Harbour the winter plankton was characterized by large quantities of medusae (*Obelia geniculata*) and ctenophores (*Pleurobrachia pileus*) (Wear, 1965). The relationship of sea surface temperatures to the presence or absence of *Obelia* and *Pleurobrachia* was discussed by Wear. He showed that these species were most abundant when temperatures fell below 15°–16° C, and suggested that this was the upper lethal temperature for their development. In Perseverance Harbour both of the above species, as well as medusae of *Phialella,* were absent when temperatures remained below 7°–9° C (April–May), and did not reappear until temperatures rose again in late spring (Fig. 3). These species, therefore, may not be able to survive at temperatures below 7° C and this is probably the lower lethal limit for *Obelia, Pleurobrachia,* and *Phialella.* Ralph and Thomson (1968) have further discussed this relationship between temperature and *O. geniculata.*

Immediately after the winter minimum sea surface temperatures had been reached, the spawning of *Munida subrugosa, Nauticaris marionus,* and *Pagurus campbelli* began. The onset of spawning in many marine animals is stimulated by the initial rise in temperature (Orton, 1920; Kinne, 1963), and the decapod Crustacea of Perseverance Harbour are not atypical in this respect. In 1966 the earlier appearance and the earlier "mid-breeding season" of both *N. marionus* and *P. campbelli* were probably related to the earlier spring rise of sea surface temperatures in that year.

Consistently lower numbers of decapod larvae in the spring of 1965 as compared with those in 1966 (Fig. 6) may indicate a less successful breeding season in the former year in Perseverance Harbour. Very few decapod larvae (one or two per sample) were collected in spring 1967, which indicated an almost complete breeding failure for that season. In Otago Harbour red coloration of the water caused by large numbers of *Munida gregaria* larvae occurred in some years, but larvae were almost absent in following years (Thomson and Anderton, 1921). In the North Sea a scarcity of decapod larvae in 1947 was thought to have been caused by low bottom temperatures before the onset of breeding (Rees, 1952). The failure of breeding in Perseverance Harbour during spring 1967 may also have been a result of extremely cold temperatures. During autumn, winter, and spring of that year, very low sea surface temperatures were recorded (Fig. 3).

It appears that the breeding season of the Perseverance Harbour decapod crustacean fauna is more like that of temperate rather than polar waters. In northeastern Greenland (lat 70° N) and Antarctica, breeding of marine animals was restricted to 2 or 3 months during summer (Thorson, 1936). Thorson showed that only a few species with pelagic larvae occurred in these northern latitudes and the presence of the larvae was limited by phytoplankton production (which depended on light) rather than by temperature.

As an example of the situation in temperate waters Wear (1965) showed that in Wellington Harbour (lat 40° S) many decapod crustacean larvae were present throughout the year, though the larvae of some species were more abundant during spring. At the Auckland Islands (lat 51° S) Dawbin (1955) found that decapod larvae occurred only during spring. However, examination of Dawbin's collections showed that only spider crab larvae were caught. Other decapods such as *Munida subrugosa, Nauticaris marionus,* and *Halicarcinus planatus* are common at the Auckland Islands (Dawbin, 1955; Yaldwyn, 1958; and personal observations) and the absence of their larvae indicates that Dawbin's comments were not applicable to these species. The situation in Perseverance Harbour (lat 52° S) thus resembles that of temperate waters, with most decapod species producing larvae which are present during spring, summer, and autumn, but with a lesser number (e.g., *N. marionus* and *P. campbelli*) also breeding in winter.

The plankton of Perseverance Harbour is typical of that of inlet waters (Yamazi, 1956), with both local and oceanic faunas present. For most of the sampling period only the local element occurred, but occasionally off-shore plankton intruded. For example, during October and November 1967 the samples contained many oceanic species previously unrecorded or found in very low numbers: *Calanus tonsus, C. australis, Eucalanus longiceps, Eucalanus* sp., *Euchaeta* sp., *Serratosagitta tasmanica, Flaccisagitta gazellae,* a tomopterid polychaete, and a cephalopod mollusc larva. There were many days of gale force westerlies in October 1967, and this may have resulted in removal of surface water from the harbor and replacement by subsurface water of oceanic origin.

SUMMARY

1. The presence and seasonal occurrence of the plankton of Perseverance Harbour, Campbell Island, is described from 118 surface plankton samples collected with a 2-foot-diameter cone-net of 0.65 mm or 1 mm mesh.
2. In Perseverance Harbour, there is a narrow range of mean annual sea surface temperature and the harbor water is influenced more by air temperature than that of the surrounding ocean. Minimum temperatures are usually recorded in July or August and maximum temperatures in January or February.
3. A monthly frequency index is given for each of the one species of phytoplankton and 22 species of zooplankton identified and for some of the more frequently occurring plankton groups. Species not previously recorded from Campbell Island include the mysid *Tenagomysis tenuipes,* the stomatopod *Heterosquilla spinosa,* and the euphausid *Thysanoessa macrura.* Two new species of ostracod and one new species of decapod Crustacea are recorded.
4. Over half the species present in the plankton are Crustacea and spring samples are dominated by decapod crustacean zoea larvae.
5. Summer and autumn samples are dominated by medusae and ctenophores. The hydromedusa *Bougainvillia macloviana* occurs throughout the year but other hydromedusae (*Obelia geniculata* and *Phialella quadrata*) and the ctenophore *Pleurobrachia pileus* do not occur when temperatures fall below 7° C. The general absence of medusae, ctenophores, and decapod Crustacea results in very low numbers of animals in the winter samples.
6. The release of decapod crustacean larvae began immediately after sea surface temperatures rose after the winter minimum. The midbreeding season of six of the eight species of decapod Crustacea occurred from September to early November, with smaller numbers of larvae of some species being released throughout the year.
7. The number of decapod larvae showed considerable annual variation. Zoea larvae were less abundant in 1965 than 1966, and in 1967 very few zoea larvae occurred. Low numbers in 1967 were probably related to abnormally low spring sea temperatures.
8. Oceanic species are sometimes recorded and probably enter the harbor in subsurface oceanic water when surface water is removed by strong winds.

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